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Research Article

Self-awareness and self-regulatory learning as mediators between ChatGPT usage and pre-service mathematics teacher's self-efficacy

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This study aimed to examine the effect of ChatGPT usage on pre-service mathematics teachers 'self-efficacy in mathematics learning. The study further examined the mediating role of self-awareness and self-regulatory learning on the nexus between ChatGPT Usage and pre-service mathematics teachers' self-efficacy. The study adopted a survey approach using a structured questionnaire for collecting a data from sample of 352 pre-service mathematics teachers. The data obtained was analyzed using Structural Equation Modeling run from Amos (v.23) software. The study found that ChatGPT usage had a significant direct positive effect on pre-service mathematics teachers' self-efficacy and self-regulatory learning. Additionally, self-regulatory learning positively influences self-efficacy and partially mediates the relationship between ChatGPT usage and self-efficacy. Finally, self-awareness also plays a positive, partial mediating role in the connection between ChatGPT usage and self-efficacy in mathematics learning. Teacher education programs should incorporate training on how to effectively use AI tools like ChatGPT in mathematics education. This could include workshops, tutorials, and hands-on experience that demonstrate how to leverage these technologies for enhancing self-efficacy and self-regulatory skills in mathematics learning. Since AI tools are increasingly integrated into the educational context, helping pre-service teachers feel confident using ChatGPT could alleviate common anxieties surrounding technology in the classroom. Past studies have examined individual effects of ChatGPT Usage, self-awareness, self-efficacy, and self-regulatory learning. This current study extends the body of knowledge by examining the mediating effect of self-awareness and self-regulatory learning on the nexus between ChatGPT Usage and pre-service mathematics teachers' self-efficacy.

Keywords: ChatGPT usage; Pre-service mathematics teachers; Self-awareness; Self-efficacy; Self-regulatory learning

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1. Introduction

Technology integration in teaching and learning mathematics has gained attention in recent years, using AI technologies such as AI chatbots as a notable advancement. ChatGPT, which was developed by OpenAI, has become the fastest and easiest AI technology to provide accurate and dependable tools for researchers and educators. Most researcher used ChatGPT as a foundation to get accurate information to support their research works. In addition, students used ChatGPT as

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an online library tool for their academic assistance. This AI technology stands out for its versatility, and efficiency in providing fast, informative, and personalized assistance, thus helping students get knowledge and assistance (Sevnarayan, 2024). The integration of ChatGPT into mathematics education has a momentous effect on students' learning and understanding of mathematical concepts. ChatGPT aids in tutoring, language models, and research and teaching assistants (Rahman & Watanobe, 2023). Studies have explored the application of artificial intelligence (AI) in the context of teaching and learning, including chatbots, programming assistants, and language models (Lo & Hew, 2021). Several studies have examined the effect of ChatGPT on several variables such as students' interest, mathematics performance, students' anxiety in learning, and more. However, this study aimed to examine the effect of ChatGPT Usage on self-awareness, self-regulatory learning, and self-efficacy among pre-service mathematics teachers.

Self-awareness is the capacity to recognize and understand one's thoughts, feelings, and emotions, as well as how these internal states influence behavior (Morin, 2021). Self-awareness allows individuals to identify patterns in their behavior and comprehend the motivations behind their actions. Moreover, internal self-awareness helps in recognizing personal strengths and weaknesses, leading to better self-regulation and personal growth (Abdel Hadi & Gharaibeh, 2023). On the other hand, external self-awareness refers to the ability to perceive how others view one's behavior and emotions (Huggins et al., 2020). It involves understanding the impact of one's actions on others and adapting behavior accordingly. Higher external self-awareness can enhance empathy and improve social interactions.

Self-regulatory learning refers to one's ability to understand and control their learning environment (Paris & Paris, 2001). It involves a cyclical process of planning, monitoring, and evaluating one's learning. Self-regulated learners are proactive about their learning. They analyze task requirements, set productive goals, select effective strategies, monitor their progress, and adjust their approach as needed. This allows them to take greater control of their learning and become more independent and effective students (Zimmerman, 2002).

Self-efficacy is an individual's belief in their ability to accomplish goals and tasks (Matovu, 2020). It is a key concept in social cognitive theory, introduced by psychologist Albert Bandura in the 1970s (Abdullah et al., 2020). Self-efficacy refers to the confidence people have in their ability to perform specific behaviors or achieve particular outcomes (Shkëmbi & Treska, 2023). Self-efficacy influences people's choices, goals, emotional reactions, effort, and persistence (Wu et al., 2020).

1.1. Problem Statement

As AI becomes increasingly integral into education, it holds substantial potential to reshape instructional practices and support teacher development. Particularly through tolls like ChatGPT. Pre-service mathematics teachers, who are in the crucial formative stages of their teaching careers, stand to benefit significantly from such technology by using AI to enhance their understanding of complex mathematical concepts, improve lesson planning, and reinforce their teaching strategies. However, while the use of ChatGPT and similar AL-driven educational tools has surged in recent years, there remains limited research on the effect of ChatGPT usage specifically on per-service mathematics teachers' self-efficacy.

Few studies specifically examine the effect of ChatGPT usage on self-efficacy as mediated by self-awareness and self-regulatory learning. Most precisely, separate studies focus on ChatGPT usage in education (Adeshola & Adepoju, 2023), ChatGPT and mathematics performance (Asare et al., 2023; Searson et al., 2024), self-efficacy (Ali & Hafeez, 2022), self-efficacy and mathematics performance (Negara et al., 2021), self-awareness (Atmojo et al., 2020), self-regulatory learning (Spooner et al., 2022), or self-regulatory learning and mathematics performance (El-Adl & Alkharusi, 2020), without combining these variables in a singly study. The specific mechanism through ChatGPT influences self-awareness and self-regulatory learning, and in turn, influences self-efficacy are not well understood. Research is needed to investigate how using ChatGPT in mathematics learning influences students' self-efficacy in their mathematics learning. There is a

gap in studies that specifically examine the effect of ChatGPT on self-awareness, self-regulatory learning, and self-efficacy. While several studies have examined the effect of technological tools in mathematics education, there is a lack of research focusing on the effect of ChatGPT on self-efficacy, particularly within universities. This study aims to examine the effect of ChatGPT on self-efficacy, mediated by self-awareness and self-efficacy among pre-service mathematics teachers. This study will examine whether using ChatGPT in learning mathematics can predict pre-service mathematics teachers' self-awareness, self-regulatory learning, and efficacy in mathematics learning. Specifically, the objectives of this study were to:

1. Determine the effect of ChatGPT Usage on pre-service mathematics teachers' self-efficacy in mathematics learning.
2. Assess the effect of ChatGPT Usage on pre-service mathematics teachers' self-regulatory learning in mathematics.
3. Determine the effect of ChatGPT Usage on university students' self-awareness in mathematics learning.
4. Ascertain the mediating effect of self-regulatory on the nexus of ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning.
5. Ascertain the mediating effect of self-awareness on the nexus between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning.

The objectives of the study were achieved by gathering data from pre-service mathematics teachers pursuing a Bachelor of Science (Mathematics Education). The data was analyzed using structural equation modeling run from Amos (v. 23). SEM is used to examine the relationships among several variables within a single model. This approach helps researchers to determine and understand the direct effect and indirect effects among variables.

1.2. Significance of the Study

The findings of this study could be used to inform the design and implementation of teacher training curricula, with a focus on integrating AL-based tools like ChatGPT to build teaching efficacy, as ChatGPT offers immediate feedback, interactive support, and access to vast information resources, it can be leveraged in teacher education programs to facilitate skill acquisition and boost confidence in lesson planning, mathematical problem-solving, and pedagogical strategy development. Moreover, by analyzing the effect of ChatGPT on self-efficacy, this study could empower pre-service mathematics teachers to approach their training with increased self-confidence, better prepared to overcome common challenges in classroom management and instructional delivery. In addition, this study will contribute to a growing body of knowledge on AI's role in teaching development, offering evidence-based insights into how AL can positively influence teacher self-efficacy. These insights can help educational institutions and policymakers make informed decisions regarding AI implementation in teacher education, ensuring that digital resources effectively support teacher preparation rather than merely offering supplemental or redundant tools. Finally, this study's focus on pre-service teachers' self-efficacy as shaped by AI engagement will contribute valuable insights into how these future educators can use digital tools to manage their learning effectively, set educational goals, and reflect critically on their teaching practices.

2. Literature Review and Hypothesis Development

2.1. ChatGPT Usage and Self-Efficacy

Self-efficacy, a concept introduced by Bandura (2017), refers to individuals' beliefs in their capacity to organize and execute courses of action required to achieve a specific goal. In the context of education, self-efficacy affects teacher's motivation, approach to challenges, persistence, and the quality of their teaching. Pre-service teachers, who may lack experience and confidence, often benefit from interventions that enhance their self-efficacy beliefs (Han et al., 2017). Several studies have explored the effects of technology on teacher self-efficacy. For example, Wilson (2023) found

that technology use increases teacher self-efficacy by providing tools that simplify tasks and enhance teaching effectiveness. ChatGPT, with capabilities for instant feedback, resource generation, and problem-solving support, has been identified as a tool that can potentially influence pre-service teachers' self-efficacy in mathematics. Moreover, Huang (2024) found that the usage of ChatGPT in pre-service teacher training helped boost participants' confidence in their teaching abilities by providing immediate answers to their questions and enhancing their understanding of content delivery. This increase in confidence was directly corrected with an improvement in their self-efficacy beliefs. Again, a study by Getenet (2024) examined the effectiveness of ChatGPT in supporting pre-service mathematics teachers in Leeson planning and problem-solving. The study found that pre-service teachers who interacted with ChatGPT felt more equipped to tackle mathematical challenges and were more confident in their ability to explain difficult concepts. The participants reported that ChatGPT provided a sense of reassurance, particularly when they encountered complex mathematical ideas during their training. Based on these discussions, we hypothesized that;

H1. ChatGPT Usage significantly predicts pre-service mathematics teachers' self-efficacy in mathematics learning.

2.2. ChatGPT Usage and Self-Regulatory Learning

Self-regulatory learning [SRL] involves proactive, self-guided processes where learners set goals, monitor progress, and adapt strategies to achieve educational outcomes (Sabourin et al., 2013). Key SRL framework, including Zimmerman's cyclical model (Zimmerman, 2002), outlines phases such as forethought, performance, and self-reflection, which are integral to effective learning (Panadero, 2017). AI applications have been found to improve instructional quality and enhance the ability of teachers to adapt content delivery based on student needs (Chen et al., 2020). ChatGPT facilitates SRL by providing an interactive environment where users can practice goal-setting, obtain feedback, and reflect on learning processes. Recent studies have indicated that using AI chatbots enhances metacognitive skills, allowing pre-service teachers to become more aware of their learning processes (Dahri et al., 2024). With ChatGPT, they can simulate teaching scenarios, receive feedback, and self-reflect on their instructional strategies, which strengthens SRL skills (Steinert et al., 2023). Moreover, Pepin et al. (2024) found that pre-service mathematics teachers using AI-assisted platforms reported higher engagement and SRL levels. These tools support their learning autonomy and motivate them to take ownership of their learning. Similarly, a study by Ng et al. (2024) revealed that the use of chatbots in mathematics teacher education improves user's ability to self-regulate and develop instructional resilience by providing immediate, relevant feedback. Based on these discussions, the researchers proposed that;

H2. ChatGPT usage significantly predicts pre-service mathematics teachers' self-regulatory learning in mathematics.

2.3. ChatGPT Usage and Self-Awareness

Self-awareness in learning encompasses a teacher's ability to recognize personal learning needs, strengths, and areas for development. It includes reflective practices that foster improved teaching skills and deeper engagement in professional development. On the other hand, AI-driven platforms like ChatGPT have the potential to enhance self-awareness in pre-service mathematics teachers by providing personalized, on-demand support, encouraging reflective practice, and improving metacognitive skills. A study by Han et al. (2024) showed that AI-based educational tools support self-directed learning by offering continuous feedback, which encourages students to actively assess their learning. These findings suggest that similar AI tools, such as ChatGPT, could enhance self-awareness in pre-service teachers. Moreover, Dahri et al. (2024) found that using AI-powered tools for reflective journaling led to greater self-awareness and resilience among pre-service teachers. Further, Kim et al. (2024) highlighted that AI-driven tutoring systems help foster metacognitive skills, which are a fundamental component of self-awareness. These systems encourage learners to question their thought processes and deepen their understanding, showing

potential for ChatGPT to similarly engage pre-service teachers in reflective thinking. The researchers, therefore, hypothesized that;

H3. ChatGPT usage significantly predicts pre-service mathematics teachers' self-awareness in mathematics learning.

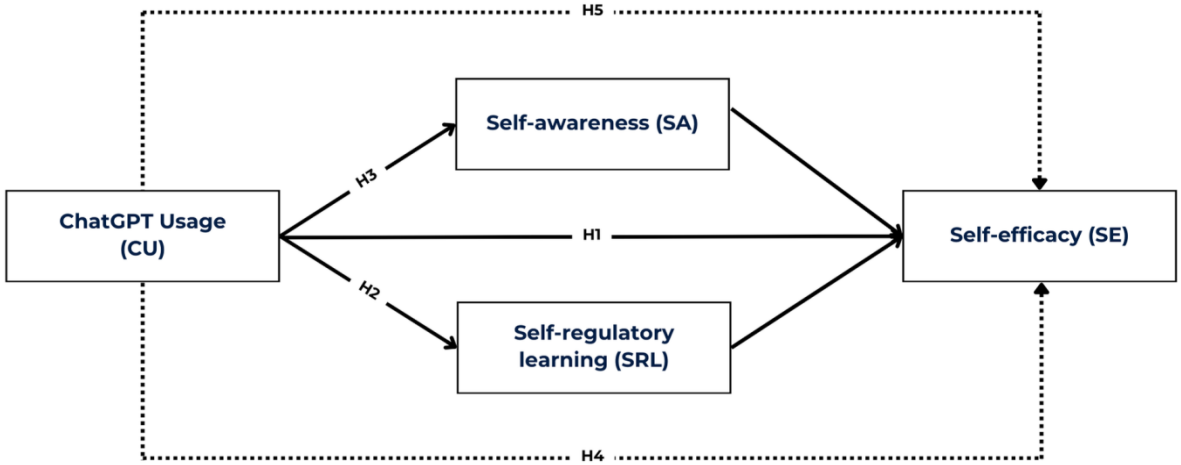
Based on hypotheses 2 & 3, it was found that ChatGPT usage significantly predicts university students' self-awareness in mathematics learning. Further, ChatGPT usage significantly predicts pre-service mathematics teachers' self-regulatory learning in mathematics. From these hypothesized, Based on these, the researchers proposed that;

H4. Self-regulatory learning mediates the relationship between ChatGPT usage and pre-service mathematics teachers' self-efficacy in mathematics learning.

H5. Self-awareness mediates the relationship between ChatGPT usage and pre-service mathematics teachers' self-efficacy in mathematics learning.

Figure 1 presents the conceptual framework.

Figure 1
Conceptual Framework



From Figure 1, ChatGPT Usage [CU] serves as the independent variable, self-awareness, and self-regulatory learning are independent variables, and self-efficacy is the dependent variable. Moreover, ChatGPT Usage shows a direct effect on self-awareness, self-regulatory learning, and self-efficacy among pre-service mathematics teachers. In addition, self-awareness and self-regulatory learning show a direct effect on self-efficacy. Finally, self-efficacy and self-regulatory learning mediate the nexus between ChatGPT Usage and self-efficacy among pre-service mathematics teachers in mathematics learning.

3. Method

3.1. Research Design

A quantitative approach utilizing a cross-sectional survey was used in this study. Cross-sectional design examines the relationship among variables within a target population during a specified timeframe (Downs, 1990). One thousand eight hundred and fifty-one (1851) pre-service mathematics teachers' were the focus population for the study. These participants had already enrolled in BSc. Mathematics Education at AAMUSTED, Kumasi-Ghana. The participants for the study were estimated using Yamane's (1967) formula from the total population of 1851 pre-service mathematics teachers. The sample size for the study was estimated as three hundred and twenty-nine (329) pre-service mathematics teachers. The study employed stratified sampling of pre-service mathematics teachers by academic level (100, 200, and 300) with a total sample size of 174 for level 100, 80 for level 200, and 75 for level 300. Simple random sampling was then applied to select specific participants from each level. Slips of papers marked "Yes" were used to indicate selected participants (147 for level 100, 80 for level 200, and 75 for level 300), while "No" slips accounted for

the remaining populations: 807 for level 100, 370 for level 200, and 345 for level 300. This ensures an unbiased selection of participants for the questionnaire.

3.2. Instruments

The data for the study was collected through a structural questionnaire, which comprised five parts. The first part of the questionnaire, section A solicits the demographic characteristics of the respondents (that is, level of education). Section B comprised various questions that measure ChatGPT Usage. Section C comprised various questions that measure self-awareness. Section D comprised various questions that measure self-regulatory learning, while Section E comprised various questions that measure self-efficacy. A point Likert scale of 1-marvelously disagree, 2-disagree, 3-neutral, 4-agree, and 5-marvelously agree was used to evaluate the measurement items from Section B to Section E. Eight (8) measurement items for ChatGPT usage were adapted from Asare et al. (2023) and Sánchez-Ruiz et al. (2023). Moreover, five (5) measurement items for self-awareness were adapted from Demetriou et al. (2020). In addition, five (5) measurement items for self-regulatory learning were adapted from Dunn et al. (2012). Finally, ten (10) measurement items for self-efficacy were adapted from Negara et al. (2021).

3.3. Ethical Declaration

According to the authors, formal ethical approval was not necessary for this investigation. The researchers, however, adhere to moral guidelines pertinent to science. The poll was administered to the pre-service teachers who were the participants. Before the data collection, informed consent was acquired, and confidentiality was scrupulously upheld. The students who declined to take the poll did not suffer any consequences or feel under any kind of duress.

3.4. Validity and Reliability

To validate the measurement items, an expert in mathematics education to ensure each question accurately measured the intended variables and clarified ambiguous wording reviewed the instrument. The data was then audited, crosschecked with other sources, and analyzed statistically. For reliability, the researchers conducted exploratory factor analysis [EFA] to confirm the grouping of items under their respective variables. Reliability was assessed using SPSS (v.23), with Cronbach's alpha value required to be at least 0.7 for the items to be considered reliable. The reliability results are displayed in Table 1.

Table 1
Reliability Analysis

Variables	*Number of Items*	*Cronbach's Alpha Value (**α**)*
ChatGPT Usage (CU)	4	.953
Self-Awareness (SA)	4	.950
Self-Regulatory Learning (SRL)	3	.974
Self-Efficacy (SE)	6	.983

From Table 1, ChatGPT had four (4) measurement items, self-awareness had four (4) measurement items, self-regulatory learning had three (3) measurement items, and self-efficacy had six (6) measurement items with their Cronbach's alpha score of 0.953, 0.950, 0.974, and 0.983 respectively. The Cronbach's Alpha values for all the constructs with their number of items were higher than the minutest starting point of 0.7, indicating there was high internal consistency (trustworthiness) among the measurement items.

3.5. Exploratory Factor Analysis

The researchers used SPSS (v.23) to perform Exploratory Factor Analysis on the collected data to identify the number of measurement items loaded onto their respective constructs. items with standardized loading below 0.5, as well as item(s) with no or incorrect loading(s), were removed. Principal Component Analysis was used for extraction, with Varimax rotation and Kaiser

Normalization. The rotation converged in five iterations, with each extracted factor having an Eigenvalue greater than 1. The EFA results are shown in Table 2.

Table 2
Exploratory Factor Analysis

Rotated Component Matrix				
Measurement Items	Component			
	1	2	3	4
CU5		.944		
CU6		.858		
CU7		.917		
CU8		.904		
SA1			.938	
SA2			.936	
SA4			.845	
SA5			.929	
SRL1				.919
SRL2				.923
SRL3				.929
SE1	.937			
SE2	.935			
SE4	.916			
SE8	.920			
SE9	.932			
SE10	.931			
KMO and Bartlett's Test				
Total Variance Explain [TVE]				90.58%
Kaiser-Meyer-Olkin Measure of Sampling Adequacy				.862
Bartlett's Test of Sphericity	Approx. Chi-Square			9191.68
	df			136
	Sig.			.000
Determinant				4.74E-01

The analysis in Table 2 shows that the measurement items loaded well onto their respective constructs: ChatGPT Usage (4 items), self-awareness (4 items), self-regulatory learning (3 items), and self-efficacy (6 items), each surpassing the loading threshold of .5 (Asare et al., 2024; Dogbe et al., 2023; Marsh et al., 2020). The Kaiser-Meyer-Olkin [KMO] value exceeded the recommended 0.6, indicating high factorability, while Bartlett's test of sphericity was significant ($p < .05$), confirming the appropriateness of the correlation matrix for factor analysis. The total variance explained was 90.58%, far above the 50% benchmark, and the determinant value of 0.474 supported the adequacy of the correlation matrix. With a sampling adequacy of 86.2% and a significant Chi-square (9191.68, $p < .05$), all criteria were met, ensuring the sample's suitability for hypothesis testing.

3.6. Confirmatory Factor Analysis

After EFA met the acceptable requirement, Confirmatory Factor Analysis [CFA] was further run in Amos (v.23) by using the retained measurement items from the EFA using the same data. Just like the EFA, the required standardized factor loadings for each measurement item are expected to be at least 0.5. From Table V, the least factor loading for the measurement items was 0.799 (SRL2), which indicated that all the measurement items had a factor loading greater than the accepted starting point of 0.5. This indicates that the measurement items positively affect the proposed latent variables. Table 3 presents confirmatory factor analysis results.

Table 3
Confirmatory Factor Analysis

Variables	*MI*	*SFL(s)*	*Sig. value*
ChatGPT Usage [CU]			
ChatGPT helps me understand difficult mathematics concepts.	(CU5)	.931	.000
I find ChatGPT useful as a supplementary tool for solving math problems.	(CU6)	.858	.000
Using ChatGPT improved my confidence in approaching mathematics tasks.	(CU7)	.981	.000
ChatGPT encourages me to explore mathematical topics beyond my coursework.	(CU8)	.851	.000
Self-Awareness [SA]			
I can identify areas in mathematics where I need improvement.	(SA1)	.952	.000
I am conscious of how my attitude towards math affects my learning.	(SA2)	.926	.000
I regularly reflect on my understanding of mathematical topics after studying.	(SA4)	.799	.000
I can recognize when I need help or additional resources to understand math concepts.	(SA5)	.960	.000
Self-Regulatory Learning [SRL]			
I set specific goals for myself when studying mathematics.	(SRL1)	.923	.000
I monitor my progress in mathematics and adjust my study strategies as needed.	(SRL2)	.977	.000
I evaluate my performance in mathematics to identify areas where I can improve.	(SRL3)	.989	.000
Self-Efficacy [SE]			
I feel confident in my ability to explain mathematical concepts clearly to students.	(SE1)	.960	.000
I believe I can effectively address students' questions and misunderstandings in mathematics.	(SE2)	.956	.000
I am confident in my ability to engage students in learning mathematics.	(SE4)	.943	.000
I feel prepared to design lessons that make mathematics understandable for my future students.	(SE8)	.929	.000
I believe I can help students develop a positive attitude toward mathematics.	(SE9)	.953	.000
I am confident that I can adapt my teaching strategies to meet diverse learning needs in mathematics.	(SE10)	.948	.000

Note. Model Fit Indices: CMIN = 308.730; DF = 103; CMIN/DF = 2.997; TLI = .971; CFI = .978; RMR = .030; RMSEA = .075; GFI = .921; SFL = Standardized Factor Loading(s); MI = Measurement Item(s)

Table 3 shows that four measurement items for ChatGPT Usage (CU5, CU6, CU7, CU8), four for self-awareness (SA1, SA2, SA3, SA4, SA5), three for self-regulatory learning (SRL1, SRL2, SRL3), and six for self-efficacy (SE1, SE2, SE4, SE8, SE9, SE10) all had loadings above the recommended threshold of 0.5. For model fitness, the study adhered to criteria from previous research (Dogbe et al., 2019; Marsh et al., 2020; Amoako et al., 2022; Asare et al., 2024), with CMIN/DF within the acceptable range (1 to 3), significant PClose (> .05), Goodness-of-fit index above 0.8, and TLI and CFI greater than 0.9. Additionally, SRMR and RMSEA were below 0.08. These model fitness indices align with the recommended standards, confirming the adequacy of the model.

Figure 1
Confirmatory Factor Analysis

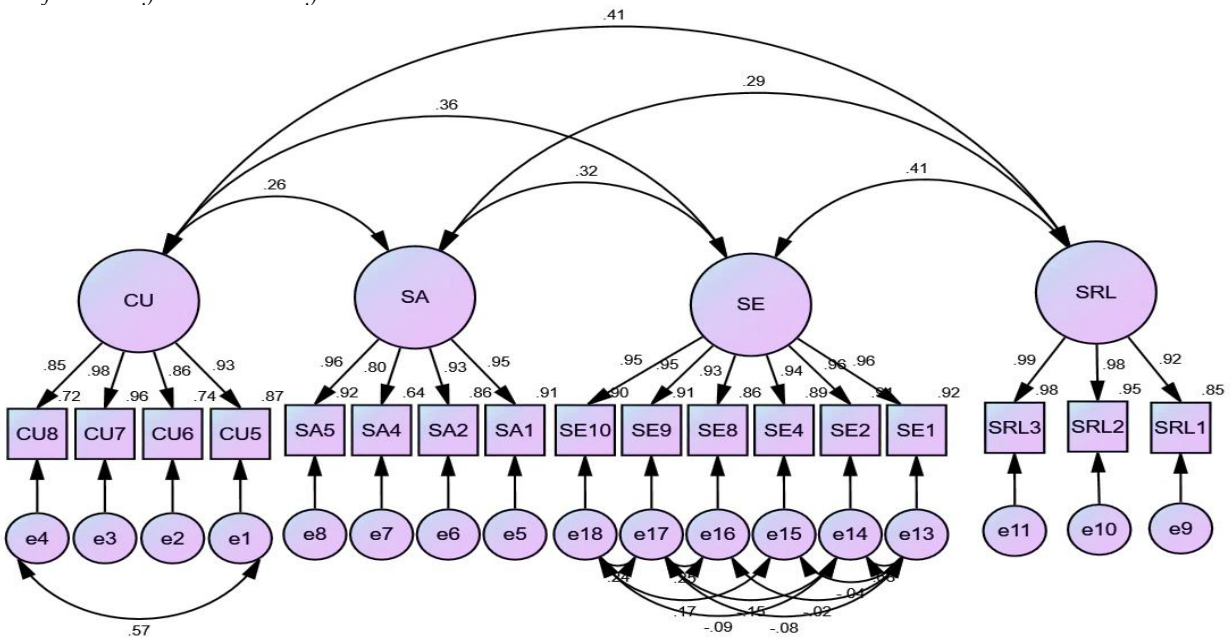


Figure 3 illustrates the graphical representation of the confirmatory factor analysis or multiple correlation illustrations. From *Figure 3* ChatGPT Usage positively correlates with self-awareness, self-efficacy, and self-regulatory learning. Moreover, self-regulatory positively correlates with both self-efficacy and self-regulatory learning. In addition, self-efficacy positively correlates with self-regulatory learning. Finally, for proper model fit indices, the researchers joined e_1 and e_1, e_{13} and e_{14}, e_{13} e_{15}, e_{14} and e_{17}, e_{14} and e_{18}, e_{15} and e_{18}, e_{16} and e_{117}, and e_{17} and e_{18}.

3.7. Discriminant Validity

CFA results were used to assess convergent validity through the average variance extracted [AVE], with all constructs achieving the required AVE of 0.5 or higher, as shown in Table VI. Discriminant validity was then confirmed by comparing the square root of each AVE to inter-correlate correlations, with the minimum $\sqrt{AVE}$ of 0.907 exceeding related correlation values (0.258, 0.412, and 0.365). Multicollinearity was not an issue, as the highest correlation between predicting variables was 0.412, well below the critical threshold of 0.8. Table 4 presents the discriminant validity findings.

Table 4
Discriminant Validity

Variables	*CR*	*AVE*	*CU*	*SA*	*SRL*	*SE*
CR	.948	.822	.907^{+++}			
SA	.951	.831	.258***	.912^{+++}		
SRL	.975	.928	.412***	.294***	.963^{+++}	
SE	.982	.899	.365***	.316***	.408***	.948^{+++}

Note. $^{+++}$ represents $\sqrt{\text{AVEs}}$ and *** denotes momentous at 1% (0.01).

From Table 4, the composite reliability [CR] values range from 0.948 to 0.982, all of which exceed the recommended threshold of 0.7. This indicates that the measurement has good internal consistency and reliability. Moreover, the average variance extracted values range from 0.822 to 0.928, with all exceeding the recommended threshold of 0.50. This suggests that the measures have good convergent validity, measuring that the items within each measure are marvelously related.

4. Results

The research used Structure Equation Modeling [SEM] to estimate the hypothesized paths, run in Amos (v.23). The study results are presented in Table 5.

Table 5
Paths Summary

Research Hypotheses	*Direct Effect*	*Std. Estimate*	*Standard Error*	*Critical Ratio*	*p*
1	CU→SE	.191	.050	3.820	<0.01
2	CU→SRL	.339	.042	8.017	<0.01
3	CU→SA	.229	.047	4.872	<0.01
	Indirect Effect	*Std. Estimate*	*Lower BC*	*Upper BC*	*p*
4	CU→SRL→SE	.110	.065	.165	.000
5	CU→SA→SE	.082	.042	.138	.000

Source: Authors' creation (2024)

4.1. ChatGPT Usage and Pre-service Mathematics Teachers' Self-Efficacy in Mathematics Learning

Hypothesis 1 proposed that ChatGPT Usage significantly predicts pre-service mathematics teachers' self-efficacy in mathematics learning. This was analyzed by the direct effect of ChatGPT Usage on pre-service mathematics teachers' self-efficacy in mathematics learning. The inform Table 5, the researchers realized that ChatGPT Usage had a direct positive and momentous effect on pre-service mathematics teachers' self-efficacy in mathematics learning with a p-value less than 1% ($\beta = .339; CR = 8.017$). Hypothesis one (H1): "ChatGPT Usage significantly predicts pre-service mathematics teachers' self-efficacy in mathematics learning", was thus supported by this study.

4.2. ChatGPT Usage and Pre-service Mathematics Teacher Self-Regulatory Learning in Mathematics

The second hypothesis proposed that ChatGPT Usage significantly predicts pre-service mathematics teachers' self-regulatory learning in mathematics. This was analyzed by the direct effect of ChatGPT Usage on pre-service mathematics teachers' self-regulatory learning in mathematics as presented in Table 5. From Table 5, the researchers realized that ChatGPT Usage had a direct positive and momentous effect on pre-service mathematics teachers' self-regulatory learning in mathematics, with a p-value less than 1% ($\beta = .339$; CR = 8.017). The result validated that ChatGPT Usage had a 33.9% positive direct effect on pre-service mathematics teachers' self-regulatory learning in mathematics. Hypothesis 2 (H2) was supported by the study, showing that ChatGPT usage has a direct and momentous effect on pre-service mathematics teachers' self-regulatory learning in mathematics.

4.3. ChatGPT Usage and Pre-service Mathematics Teacher Self-Awareness in Learning Mathematics

The third hypothesis proposed that ChatGPT Usage significantly predicts pre-service mathematics teachers' self-awareness learning in mathematics. The result was analyzed by the direct effect of ChatGPT Usage on pre-service teacher self-awareness in mathematics learning. From Table 5, the researchers realized that ChatGPT Usage positively and substantially influences pre-service teacher self-awareness in mathematics learning, with a p-value less than 1% ($\beta = .229$; CR = 4.872). This result validated that ChatGPT Usage had a 22.9% positive effect on pre-service mathematics teachers' self-efficacy in mathematics learning. Therefore, the study confirms hypothesis 3 (H3), demonstrating the positive effect of ChatGPT Usage on pre-service mathematics teachers' self-awareness in mathematics learning.

4.4. Self-Regulatory Learning Mediates the Relationship Between ChatGPT Usage and Pre-ervice Mathematics Teacher's Self-Efficacy in Mathematics Learning

The fourth hypothesis sought to propose self-regulatory learning to mediate the relationship between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning. From Table 5, the researchers realized that both lower and upper BCs were positive, indicating that ChatGPT Usage had a positive effect on pre-service teacher self-efficacy through their self-regulatory learning in mathematics. The result found that self-regulatory learning was found to be partially mediating between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning, as shown by the Table 5 standardized constant for the path being .110 and its significance validated by not having zero between its upper and lower. As a result, the study's findings were consistent with hypothesis 4 (H4), which suggests that self-regulatory learning plays a mediating role in the relationship between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning.

4.5. Self-Awareness Mediates the Relationship between ChatGPT Usage and Pre-service Teachers' Self-Efficacy in Mathematics Learning

The last hypothesis proposes self-awareness mediates the relationship between ChatGPT Usage and pre-service teachers' self-efficacy in mathematics learning. From Table 5, the researchers realized that both lower and upper BCs were positive, indicating that ChatGPT Usage had a positive effect on pre-service teacher self-efficacy through their self-awareness in mathematics learning. The result found that self-awareness was found to be partially mediating between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning, as shown by the Table 5 standardized constant for the path being .082 and its significance demonstrated by not having zero between its upper and lower. This supports hypothesis 5 (H5), which suggests that self-awareness plays a mediating role in the link between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning.

Figure 2
Paths Summary

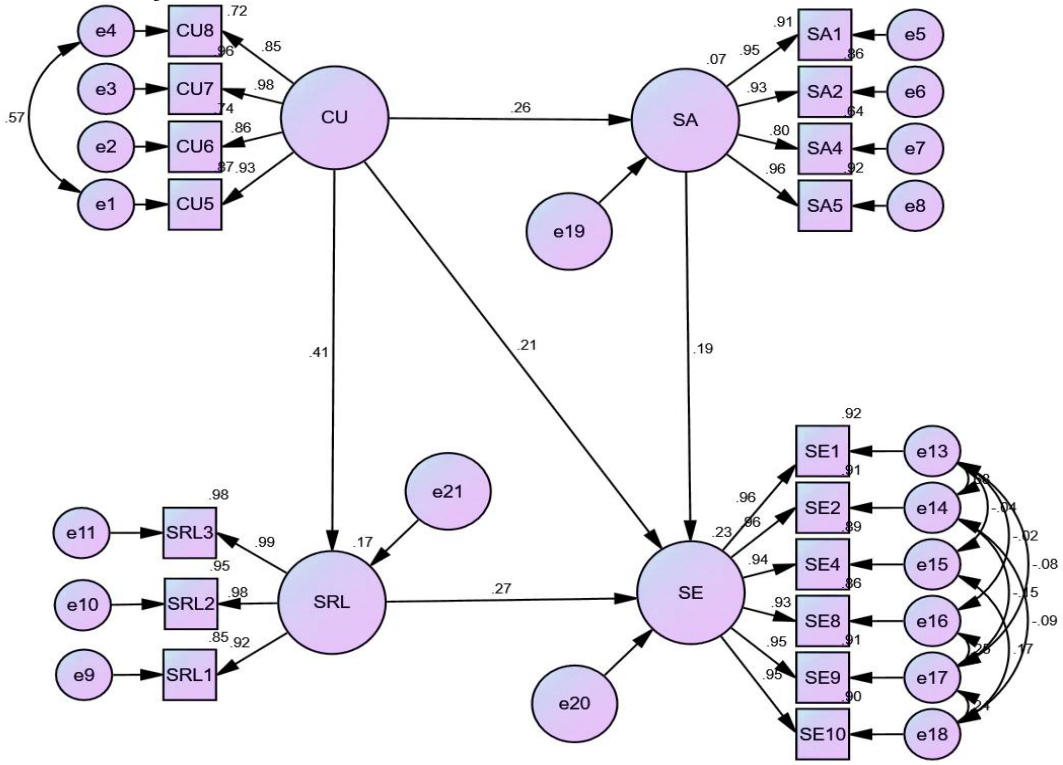


Figure 4 illustrates the path summary. From Figure 4, ChatGPT Usage has a direct positive effect on self-regulatory learning, self-awareness, and self-efficacy. Moreover, self-regulatory

learning had a direct effect on self-efficacy. In addition, self-awareness has a direct effect on self-efficacy. Finally, for proper model fit indices, the researchers joined e_1 and e_1, e_{13} and e_{14}, e_{13} e_{15}, e_{14} and e_{17}, e_{14} and e_{18}, e_{15} and e_{18}, e_{16} and e_{117}, and e_{17} and e_{18}.

5. Discussion

This section provides a discussion of results, in line with the research questions of the study. While several studies have examined the effect of ChatGPT Usage on mathematics performance, this study focused on the effect of ChatGPT Usage on pre-service mathematics teachers' self-efficacy in mathematics learning. The analysis reveals that ChatGPT usage has a direct positive effect on self-efficacy among pre-service teachers. These findings align with recent literature highlighting the role of AI-based educational tools in fostering self-efficacy among learners. For example, Halkiopoulos and Gkintoni (2024) found that AL-based applications in mathematics education enhance students' self-efficacy by providing timely feedback, tailored instructional support, and an adaptive learning environment. This evidence is consistent with the present study that, ChatGPT's responsive nature and personalized guidance could similarly empower pre-service teachers, boosting their confidence in tackling mathematical concepts. Lu et al. (2018), who demonstrated that the integration of AL tools in teacher training programs positively influences teacher confidence and self-perception of skills, particularly in complex subjects like mathematics, could find further support for these results in recent research. This study highlights that interactive AL platforms, such as ChatGPT, may bridge gaps in pre-service teacher's understanding and self-efficacy by offering on-demand support, thus enhancing their self-efficacy. Additionally, the positive effect of ChatGPT usage on self-efficacy in the current study could be related to the "scaffolding" effect that AL tools provide, as discussed by Lee et al. (2024). According to their findings, AL tools facilitate a scaffolding process by breaking down complex tasks and progressively challenging users, which can contribute to gradual skill mastery and an improved self-efficacy outlook. This gradual and supportive learning process aligns with Bandura's self-efficacy theory, which emphasizes the importance of successful experience and feedback in strengthening an individual's belief in their abilities (Bandura et al., 1996).

Moreover, the result revealed that ChatGPT Usage had a direct positive and momentous effect on pre-service mathematics teachers' self-regulatory learning in mathematics. The result validated that ChatGPT Usage had a 33.9% positive direct effect on pre-service mathematics teachers' self-regulatory learning in mathematics. These findings align with recent literature that ChatGPT significantly influences pre-service mathematics teachers' self-regulatory learning in mathematics. For example, Sharma et al. (2024) found that digital learning platforms enhanced students' self-regulatory skills by providing personalized feedback and adaptive learning paths. ChatGPT, with its ability to tailor responses to individual learners' needs, similarly facilitates metacognitive reflection and planning, key components of SRL. Moreover, Ng et al. (2024) conducted a study on the integration of ChatGPT in the mathematics classroom and found that students who used the tool exhibited improved time management and strategy selection, key facets of SRL. In their study, the participants were able to interact with ChatGPT to obtain problem-solving tips and clarifications on complex topics, which boosted their confidence and motivation, enhancing their ability to regulate their learning outcomes. In the context of pre-service mathematics teachers, Bilad et al. (2023) examined the use of AI tools in teacher education. Their study demonstrated that pre-service teachers who engaged with AI-supported platforms reported better control over their learning goals, task persistence, and adaptive learning strategies. The findings from this research align with the direct effect of ChatGPT on SRL, as observed in the current hypothesis.

The results further pointed out that, ChatGPT Usage has a positive and momentous effect on pre-service teacher self-awareness in mathematics learning. This result validated that ChatGPT Usage had a 22.9% positive effect on pre-service mathematics teachers' self-efficacy in mathematics learning. The positive influence of ChatGPT on pre-service teachers' efficacy self-awareness in mathematics learning is consistent with findings from a study on blended learning methodologies

in engineering education (Sánchez-Ruiz et al., 2023). Their research demonstrated that students quickly adopted ChatGPT, showing high confidence and general usage in their learning processes. Such confidence could transfer to pre-service teachers, enhancing their self-awareness and self-efficacy in teaching mathematics. A study by Szabo et al. (2020) highlighted that AI-based systems assist pre-service teachers in developing problem-solving skills, which are essential for teaching mathematics effectively. The integration of ChatGPT allows for diverse strategies in problem-solving, fostering a deeper understanding of mathematical concepts among pre-service teachers (Getenet, 2024). Moreover, research by Dilling and Herrmann (2024) found that ChatGPT can help manage cognitive loading by providing immediate feedback and support during mathematical reasoning tasks. This immediate assistance can enhance self-awareness as teachers become conscious of their thought processes and learning strategies.

Furthermore, the findings from this study also demonstrate that the effect of ChatGPT Usage on pre-service teacher self-efficacy in mathematics learning is not just direct but partially mediated through self-regulatory learning. This is one of the major contributions of the study.

Finally, the findings from this study also demonstrate that the effect of ChatGPT Usage on pre-service teacher self-efficacy in mathematics learning is not just direct but partially mediated through pre-service mathematics teachers' self-awareness in mathematics learning. This is one of the key contributions of the study.

6. Practical Implications

Teacher education programs should incorporate training on how to effectively use AI tools like ChatGPT in mathematics education. This could include workshops, tutorials, and hands-on experience that demonstrate how to leverage these technologies for enhancing self-efficacy and self-regulatory skills in mathematics learning. In addition, an educator should emphasize the importance of self-regulatory learning skills in their programs. Workshops or modules that teach time management, goal setting, and self-assessment can complement the use of AI tools, leading to improved self-efficacy. Moreover, encouraging pre-service teachers to reflect on their learning processes and outcomes can promote self-awareness. Programs could integrate reflective practices, such as a journal or peer discussions, to help teachers understand how their interactions with AI tools affect their learning and confidence. Furthermore, in-service training for current teachers should include sessions on using AI tools like ChatGPT. This can help them integrate these resources into their teaching practices, thereby enhancing their pedagogical skills and supporting their student' learning. Furthermore, facilitates collaborative learning environments where pre-service teachers can share their experiences and strategies using ChatGPT. Finally, educational policymakers should consider creating guidelines for the use of AI tools in teacher education. Establishing a framework can ensure that technology use aligns with pedagogical goals and promotes positive educational outcomes.

7. Social Implications

The direct effect of ChatGPT on pre-service teachers' self-efficacy and self-regulatory learning suggests that AI tools like ChatGPT can effectively complement traditional teacher training programs. By using AI to build confidence and promote independent learning, educational institutions can produce more competent and self-assured future educators, potentially leading to a stronger workforce of mathematics teachers who are prepared to handle classroom challenges In addition, since AI tools are increasingly integrated into the educational context, helping pre-service teachers feel confident using ChatGPT could alleviate common anxieties surrounding technology in the classroom. Moreover, given the demonstrated positive impact of ChatGPT on self-efficacy, teacher education programs may consider adopting AI-driving platforms more widely to improve pre-service teachers' confidence, autonomy, and self-awareness. This shift can contribute to a more progressive, evidence-based educational approach that leverages technology to support individual learning needs and teacher preparedness.

8. Conclusions

The findings revealed that ChatGPT Usage had a direct positive and statistically momentous effect on pre-service mathematics teachers' self-efficacy in mathematics learning. Moreover, the result validated that ChatGPT Usage had a 33.9% positive direct effect on pre-service mathematics teachers' self-regulatory learning in mathematics. In addition, ChatGPT usage had a 22.9% positive effect on pre-service mathematics teachers' self-efficacy in mathematics learning. Furthermore, there exists a momentous and indirect effect of self-regulatory learning between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning. Finally, there exists a momentous and indirect partial effect of self-awareness between ChatGPT Usage and pre-service mathematics teachers' self-efficacy in mathematics learning.

Broader implications of these findings suggest that integrating AL-based platforms in teacher education programs could be instrumental in developing reflective and self-directed learners. For teacher educators, this insight calls for embedding such tools into curricula as scaffolding mechanisms that enhance self-efficacy and facilitate a strong alignment with autonomous learning objectives.

9. Limitations and Further Research

While the findings are strong, some limitations should be considered. The results may not generalize to other populations or subjects, and further study is needed to understand how ChatGPT interacts with various factors in the educational environment, including other learning tools and pre-service teachers' attitudes toward technology. Further research could explore which specific ChatGPT features best support self-regulatory learning, self-awareness, and self-efficacy, as well as the effect of prolonged use on skill development. Additionally, this study focused on self-regulatory learning and self-awareness as mediators between ChatGPT usage and self-efficacy in math learning; however, these factors might also act as moderators, as potential areas for future investigation.

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Declaration of interest: The authors declare that no competing interests exist.

Data availability: Data generated or analyzed during this study are available from the authors on request.

Ethical declaration: The authors confirmed that the study received approval from the Department of Mathematics Education Research Ethics Committee of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Kumasi-Ghana, on July 17, 2024, under Ref No.: AAMUSTED/IERD/2024/001. Written informed consent was obtained from Head of Departments, lecturers, and students before their participation.

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